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A Hierarchical Analysis of Air Battle Management Team Goals in the Defensive Counter Air Mission

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Air Operations Division
Defence Science and Technology Organisation

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ABSTRACT

The goals and sub-goals of RAAF Air Battle Management (ABM) teams were analysed in order to support scenario design, performance measurement, and feedback for ABM team training research exercises. This technical note provides a description of the resultant ABM team goal hierarchy and its development within the DSTO research task AIR 04/236 'Future Air Warfare Technology and Training'.

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Executive Summary

A number of team training research exercises have been conducted under the DSTO research task AIR 04/236 'Future Air Warfare Technology and Training'. These events have been conducted with the aim of understanding and enhancing the training of RAAF Air Battle Management (ABM) teams through the application of distributed simulation and other advanced training-support technologies.

As a part of developing these exercises, the goals and sub-goals of ABM teams were analysed for a relatively well-understood mission: the defensive counter air (DCA) mission. This analysis was guided by the Hierarchical Task Analysis for Teams (HTA-T) approach (e.g., Annet, Cunningham, & Mathias-Jones, 2000). The analysis resulted in a hierarchical description of ABM team goals that was linked at the highest level to the Australian Joint Essential Tasks list (ASJETs; McCarthy, Kingston, Johns, Gori, Main, & Kruzins, 2003). This goal hierarchy represents a description of *what* goals ABM teams work to achieve, as well as *why* and *how* they go about achieving them.

The ABM team task hierarchy provided the basis for scenario design, performance measurement, and feedback for ABM team training research exercises under AIR 04/236 and was the subject of revision and improvement over the lifespan of that task (2004-2007). This technical note provides a description of the ABM team goal hierarchy and its development. It is concluded that this technique holds promise for future applications in the areas of team training, operational evaluation, and readiness management.

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Contents

1. Introduction

In complex work environments, much of what is achieved involves the coordinated action of teams of individuals (Marks, Mathieu, & Zaccaro, 2001). As such, the ability of teams to achieve their collective goals is an important indicator of the operational readiness of the organisation of which they are a part. One of the most important determinants of team performance is team training. In order to design effective training and training-research strategies for a given team context, it is necessary to understand the fundamental characteristics of the work that is done by that team (Schraagen, Chipman, & Shalin, 2000).

The purpose of this technical note is to present a description of the work of the RAAF Air Battle Management (ABM) team in the defensive counter air (DCA) mission. The description presented here takes the form of a goal hierarchy. This hierarchy makes explicit the links between high-level organisational goals of the ADF, which specify why the team undertakes its work (i.e., the Australian Joint Essential Tasks; ASJETs), and relatively low-level goals of the team that are amenable to training, observation, and assessment.

2. Development and Application

There are many techniques to choose from when studying how work is achieved in a complex setting such as the ABM domain, (for overviews see Schraagen et al., 2000; Schraagen, 2006). The choice of approach determines the nature of the study's products. In turn, the nature of those products determines their utility for application to different purposes, such as the design of information-technology systems or human-machine interfaces, the allocation of tasks to human team members or machines, or the development of training strategies. In the present context, the study of ABM team tasks was undertaken with the purposes of; (1) demonstrating how training that is aimed specifically at team objectives can be applied to the ABM domain, (2) facilitating the development of training scenarios and measurement approaches judged to be effective for training ABM teams, (3) facilitating the development of a method for capturing ABM team performance and providing effective feedback at a team level, and (4) supporting research into the determinants of ABM team performance and the enhancement of such through the application of advanced training technologies.

Given these purposes, the approach that was used was a particular form of hierarchical task analysis (HTA) known as hierarchical task analysis for teams (HTA-T; e.g., Annett & Cunningham, 2000; Annett, Cunningham, & Matthias-Jones, 2000). The term hierarchical task analysis does not describe a specific procedure or the generation of strictly defined products; rather, it describes a philosophy – an approach to describing complex work systems (such as ABM teams) as a decomposition of their goals or objectives and subgoals or sub-objectives (Stanton, 2006). The aim of HTA is to identify system goals and sub-goals as well as measures which can be used to quantify or structure judgements about the degree to which goals are attained. The decomposition of goals is used to develop a hierarchical framework, in which

any higher order goal can be described in terms of a number of sub-goals[1]. The relationships between goals and sub-goals represented in HTA have been called "action means-ends" relationships (Vicente, 1999, p. 162). In hierarchies defined by such relationships, each node contains a verb statement[2] which represents an *end* that can be achieved by *means* of those nodes which link to it from below. Each node is also a *means* that can be used to achieve the *ends* represented by nodes to which it links above. As one ascends such a hierarchy, the reason *why* each goal exists is given. As one descends the hierarchy, nodes below reveal *how* each goal is achieved. HTA-T extends on the basic HTA approach by aiming to decompose the system to identify those goals and sub-goals which can only (or best) be achieved through teamwork (Annett et al., 2000).

This approach is advantageous for the purpose of supporting team training and training-research for a number of reasons. For example, the aim of describing work in a way that helps to capture judgements about the degree to which system goals are attained lends the approach to the development of tools for performance measurement, feedback, and readiness management. Also, the fact that this approach allows for the description of goals, rather than sequences of specific behaviours, allows for them to be defined in a way that affords some flexibility in determining how teams conduct their work (a positive attribute of teams), while still allowing the characteristics of *what gets done* to be formalised. Further, the goal hierarchy can highlight the links that exist between high-level goals related directly to the team's overall function, and low-level goals which feed into them. As such, these hierarchies can be applied to help understand the links between important components of training such as scenario events and the behaviours they evoke, the team's objectives, and the objectives of the team's parent organisation. When used in conjunction with an event-based approach to training (EBAT; e.g., Fowlkes et al, 1998) these links can help ensure that exercise scenarios are targeted at goals relevant for the team's operational readiness.

Development of the ABM team DCA goal hierarchy took place in an iterative fashion. The development incorporated information gathered from reviews of published documents as well as from observations and interviews conducted during research and training exercises over the course of a research program on ABM team training conducted under the DSTO task AIR 04/236 "Future Air Warfare Technology and Training". These activities involved interactions between ABM subject-matter experts from Surveillance and Control Training Unit (SACTU), 41WG, and human factors researchers from Air Operations Division, DSTO. Versions of this goal hierarchy have been trialled in support of ABM team performance measurement and feedback previously (see Best & Burchat, 2006, and Best et al., 2007), resulting in positive feedback, as well as improvements and refinements.

[1] Many goal hierarchies developed in line with the HTA approach also include 'plans' which serve to link goals by specifying the relationships between them. While plans have not been included in the ABM team DCA hierarchy to date, it is anticipated that their utility for supporting team training and assessment will be investigated as part of ongoing research.

[2] Note that the use of verb statements in HTA differentiates these representations from a different kind of means-ends representation for which Vicente is more widely known; the *structural* means-ends hierarchy which underlies the technique of work domain analysis.

While it is likely that further work is required to establish the validity and comprehensiveness of the goals and relationships between goals embodied in it, the goal hierarchy has served well in the roles for which it was designed. The approach may also have operational benefits for the RAAF beyond the original scope of the research program. It provides a good example of how future efforts aimed at defining the content of readiness evaluation and management systems might be directed. Hierarchies such as this can also act as repositories of information on the roles and responsibilities of a particular team within the broader ADF. Such team-centric views may often not be captured in organisational doctrine or individual job descriptions, but rather be left to develop organically as part of the human capital of the organisation. If this knowledge is not formalised then the inevitable turnover of personnel associated with posting cycles can lead to its loss. Once captured this knowledge can inform not only those responsible for the development and sustainment of the RAAF, but also the other organisations with which they interact. The broad application of such an approach could facilitate an enterprise-wide view of the roles and responsibilities of all teams and sub-organisations. This in turn could enable the ADF to identify where synergies and/or redundancies exist and to assess capability and readiness at an enterprise level.

3. ABM Team DCA Goal Hierarchy Description

The highest-level goals incorporated into the ABM team DCA goal hierarchy were derived from the tactical-level ASJETs (McCarthy, Kingston, Johns, Gori, Main, & Kruzins, 2003). The ASJETs were developed to represent the tasks that the ADF undertakes in the execution of its overall mission. The ASJETs describe those tasks that can or should be conducted as part of the preparation for, planning, and conduct of operations. The subset of tactical ASJETs included in the ABM goal hierarchy represents the ultimate goals to which the work of the ABM team contributes[3]. These highest-level goals, which were termed "Goal Categories" for the purpose of this analysis, are listed in Table 1.

Table 1. Goal Categories at the highest level of the ABM team goal hierarchy. These were derived from the tactical-level Australian Joint Essential Task list (ASJETs; McCarthy et al., 2003).

Goal Category Number	Goal Category Description	Associated Tactical ASJETs
1	Develop and Brief Mission Plan/Review Mission	TA 1.1.1, TA 1.1.2, TA 1.1.3, TA 1.1.4
2	Establish Military Liaison	TA 1.3.4.1
3	Manage Information Systems	TA 1.4.1.3
4	Control Airspace	TA 4.3.2
5	Conduct Defensive Counter-Air	TA 4.5.6
6	Protect Key Points and Vital Assets	TA 5.1.6

[3] It would be possible, in principle, to continue the analysis to ask why the ABM team works towards each of these top-level goals. However, Stanton (2006) argued that the purpose of the analysis must be the key consideration in deciding when to stop hierarchical decomposition. It was judged that extending these Goal Categories upward to superordinate goals such as "Defend Australia and its National Interests" would have little benefit for ABM team training scenario design, performance measurement, or feedback due to the lack of specificity in such goals.

Each of these Goal Categories was decomposed within the goal hierarchy to describe the subordinate goals undertaken by the ABM team which contributed to their achievement. The goals pursued by the ABM team which fed into the Goal Categories were termed "Team Goals" for the purpose of this analysis. Each of these Team Goals was further decomposed to describe even-more-specific contributing goals, termed "Team Sub-Goals". The decomposition stopped at the Team Sub-Goals level as it was judged that the purposes for which the analysis products were intended were not served by going further (see Section 2 above). Once each Goal Category had been decomposed down to its constituent Team Sub-Goals, each Team Sub-Goal was described in terms of (1) a purpose statement, which provided a detailed description of the sub-goal, and (2) a criterion, which provided an indication of the dimension or dimensions along which variation in Team Sub-Goal attainment should be judged. The current version of the ABM team DCA goal hierarchy is included in Appendix A as Table A1.

4. Conclusions

Throughout the course of a research program into ABM team training conducted under DSTO task AIR 04/236, an ABM team goal hierarchy was developed. The hierarchy was used to describe the goals of the RAAF ABM team in the DCA mission and to make explicit the links between relatively high-level organisational goals of the ADF that specify why the team undertakes its work (i.e., the ASJETs), and relatively low-level goals of the ABM team that are amenable to training, observation, and assessment. That goal hierarchy is the subject of this technical note.

The purpose of constructing this goal hierarchy was to support a program of team training research by providing a basis for scenario design, performance measurement, and feedback. The goal hierarchy presented here should not be considered a final product, since this research program is likely to continue under new tasking arrangements. However, it has served well in the roles for which it was designed and it provides a good example of how future efforts aimed at defining the content of readiness evaluation and management systems might be directed.

The goal hierarchy presented here represents an important contribution because the acquisition of readiness management tools such as the MENTOR software (Calytrix Technologies, Perth, Western Australia) is not sufficient to ensure effective readiness management in the ADF. The impact of such tools on the organisation will be dependent upon the quality of the material used to populate them. The development of the material used to populate such systems will present a very significant challenge if such systems are to do anything more than simply digitise current paper-and-pencil assessment methods.

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Appendix A: ABM Team DCA Goal Hierarchy

Table A1. An Air Battle Management (ABM) team goal hierarchy for the Defensive Counter Air (DCA) mission

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
1 Develop and Brief Mission Plan, Review Mission (TA 1.1.1, TA 1.1.2, TA 1.1.3, TA 1.1.4)	1.1 Brief Mission	1.1.1 Conduct Briefing	To present the brief in a manner which ensures that information is understood.	Brief is presented in a clear, concise manner
		1.1.2 Present Mission Elements IAW SOP	To cover all mission elements required for the conduct of the mission IAW the required format.	Mission elements are covered in correct order and sufficient detail
		1.1.3 Clarify Ambiguous Mission Elements	To disambiguate unclear mission elements by providing additional information or further explanation.	Ambiguity in mission elements is resolved
		1.1.4 Consider Audience Contributions	To acknowledge and discuss audience perspectives on the mission plan.	Audience perspectives on the mission plan are given due consideration
		1.1.5 Make Effective Use of Time	To ensure that the time spent discussing each mission element is concomitant with its relative importance.	Time expended on mission elements reflects their relative importance
		1.1.6 Make Effective Use of Media	To promote understanding of each mission element through the use of the most suitable presentation media.	Each mission element is presented using suitable media
	1.2 Review Mission	1.2.1 Conduct Mission Debrief	To present the debrief in a manner which ensures that information is understood.	Debrief is presented in a clear, concise manner
		1.2.2 Discuss Mission Execution IAW SOP	To cover all elements of mission execution IAW the required format.	Mission elements are covered in correct order and sufficient detail
		1.2.3 Consider Audience Contributions	To acknowledge and discuss audience perspectives on the mission execution.	Audience perspectives on the mission execution are given due consideration
		1.2.4 Make Effective Use of Time	To ensure that the time spent discussing each mission element is concomitant with its relative importance.	Time expended on mission elements reflects their relative importance
		1.2.5 Make Effective Use of Media	To promote understanding of each mission element through the use of the most suitable presentation media.	Each mission element is presented using suitable media

Continued …

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
2 Establish Military Liason (TA 1.3.4.1)	2.1 Liaise with External Agencies	2.1.1 Communicate with External Agencies	To ensure that information is understood by external agencies through clear and concise communication.	External communications are clear and concise
		2.1.2 Push Information to External Agencies	To provide relevant information to external agencies in a proactive manner, by anticipating the agency's information requirements and initiating communication.	Relevant information is 'pushed' to external agencies
		2.1.3 Pull information from External Agencies	To obtain required information from external agencies.	Relevant information is 'pulled' from external agencies
		2.1.4 Prioritise External Communications	To conduct communications with external agencies in an order that is concomitant with the relative importance of the agency and the subject of the communication.	External communications are prioritised according to relative importance
		2.1.5 Action External Communications	To adapt or modify the team's tasks, priorities, or plans in response to information received from external agencies.	Team activities are modified consistent with external inputs
3 Manage Information Systems (TA 1.4.1.3)	3.1 Manage Information	3.1.1 Build RAP	To ensure that the mission is supported through the incorportation into the command and control system of known information concerning tracked aircraft.	RAP contains sufficient information to support mission execution
		3.1.2 Maintain Accuracy of RAP	To ensure that the recognised air picture is free of false track identity, classification, or amplifying information.	RAP contains accurate information
		3.1.3 Populate Tote Board	To support shared understanding of team resources by ensuring that all known information concerning resources allocated to the ABM team is incorporated into the Tote Board.	Tote Board contains all known information concerning allocated resources
		3.1.4 Update Tote Board	To ensure that the information contained in the Tote Board is updated to reflect relevant mission events as they occur.	Tote Board information is kept current
	3.2 Manage Equipment	3.2.1 Optimise Sensor Employment	To optimise the resolution, as well as spatial, temporal, and spectral coverage of available sensors.	Sensors are optimised consistent with mission priorities

Continued …

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
3 Manage Information Systems (TA 1.4.1.3) (Continued)	3.2 Manage Equipment (Continued)	3.2.2 Deconflict Communication Channels	To ensure effective communications with all mission elements through the allocation of communication channels (i.e., mediums and devices) within the team. This includes the provision of necessary channels and the prevention of channel overload.	Communication channels are deconflicted to support mission execution
		3.2.3 Adapt Communication Systems	To adapt communications devices to suit external mission constraints such as geography, weather, and a hostile electronic warfare environment.	Communication systems are adapted to suit geography, Wx and EW
		3.2.4 Diagnose Equipment Faults	To determine the nature of detected faults through the conduct of diagnostic procedures or actions.	Equipment faults are diagnosed correctly
		3.2.5 Respond to Equipment Faults	To mitigate the effect of equipment failure by either working around or seeking rectification of the fault. If fault rectification is pursued, it is requested at a priority level commensurate with mission priorities.	Responses mitigate the impact of faults on mission execution
4 Control Airspace (TA 4.3.2)	4.1 Manage Airspace	4.1.1 Coordinate Airspace Control	To ensure that airspace sufficient to fulfil mission requirements is obtained through coordination with external airspace users. Where airspace is excess to requirements, it should be released to external users.	Controlled airspace dimensions/positions support mission execution
		4.1.2 Deconflict Airspace	To ensure the safe use of airspace within mission constraints, through the allocation of areas and/or levels to specific roles or activities.	Airspace allocation enhances mission safety
	4.2 Manage Aircraft	4.2.1 Transfer Aircraft	To ensure contiguity of control of aircraft entering or departing airspace. The transfer should occur IAW agreed procedures, which may include a NLT contact distance, entry/exit points and levels, and specified communication channels.	Aircraft control is contiguous across areas of responsibility

Continued …

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
4 Control Airspace (TA 4.3.2) (Continued)	4.2 Manage Aircraft (Continued)	4.2.2 Exchange Flight Information	To ensure that, during transition of control between team members or agencies, all relevant information regarding the status of aircraft in flight is provided in a clear and concise manner. This information may include fuel and weapon states, operating intentions, and limiting factors.	Flight information is provided in a clear, concise manner
		4.2.3 Separate Aircraft	To maintain safe separation, as defined by promulgated orders/regulations, between aircraft both inside and outside the ABM team AOR. This entails ensuring that aircraft: maintain their assigned airspace, are advised of changes to operating restrictions, and are made aware of other aircraft in close proximity and their operating intent.	Separation is maintained
		4.2.4 Respond to Separation Breakdowns	To reduce the risk of a collision, either with terrain or other aircraft by detecting breakdowns in aircraft separation and directing evasions as soon as they occur.	Directions to evade reduce the risk of a collision
	4.3 Manage Emergencies	4.3.1 Recognise Emergency Situations	To facilitate effective responses to emergency situations by detecting and determining the nature of emergencies. These may include ground and aircraft emergencies.	Emergencies are recognised in a timely manner
		4.3.2 Respond to Emergency Situations	To mitigate the effect of emergencies on safety and mission execution through the correct application of procedures and/or collaborative problem solving.	Responses mitigate the impact of emergencies on safe mission execution
	4.4 Enforce ADIZ	4.4.1 Issue Challenges	To issue the required sequence of verbal challenges to unauthorised aircraft IAW specified threshold positions and behaviours WRT the ADIZ.	Challenges are issued upon satisfaction of ADIZ threshold conditions
		4.4.2 Classify Aircraft	To apply the rules of classification embodied in the promulgated classification matrix.	Aircraft are classified IAW classification matrix

Continued …

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
4 Control Airspace (TA 4.3.2) (Continued)	4.4 Enforce ADIZ (Continued)	4.4.3 Monitor Aircraft Movements	To satisfy the ABM team as to the identity (i.e. the nature and purpose) of aircraft operating independently within or in close proximity to the ADIZ. This may involve the referencing of flight plans, monitoring of radio communications and the correlation of sensor and intelligence information.	Investigation of aircraft identity considers relevant information
5 Conduct Defensive Counter Air (TA 4.5.6)	5.1 Employ Forces	5.1.1 Prioritise Threats	To respond to threats in an order commensurate with their relative significance. This requires recognition of enemy capabilities and tactics as well as friendly vulnerabilities.	Threats are dealt with in order of significance
		5.1.2 Share Tactical Awareness	To facilitate the coordinated action of friendly forces within the AOR through the exchange and assurance of pertinent information between the ABM team and airborne forces.	Shared awareness facilitates coordinated action by friendly forces
		5.1.3 Control Fighter Intercepts	To nullify or reduce the effectiveness of hostile air action through the direction of fighters to intercept unknown or unauthorised aircraft. This involves directing targetting and intercept geometry.	Aircraft are intercepted with effective geometry
		5.1.4 Manage AAR Operations	To maximise the availability of airborne assets through the positioning of tankers within the AOR relative to receiving aircraft, and the rotation of receiving aircraft through those tankers.	AAR maximises airborne asset availability
	5.2 Manage ROE	5.2.1 Apply Current ROE	To prevent the loss of friendly forces or non-combatants and to achieve to commander's intent by the application of force IAW and through the promulgation of the rules of engagement.	Force is applied IAW ROE
		5.2.2 Modfiy ROE	To ensure that the ROE remain commensurate with the evolving tactical situation and mission requirements.	ROE is modified commensurate with the tactical situation

Continued …

Goal Category	Team Goal	Team Sub-Goal	Purpose	Criterion
6 Protect Key Points and Vital Assets (TA 5.1.6)	6.1 Protect Key Points	6.1.1 Manage Posture	To provide friendly forces sufficient time/space in which to exercise a range of redundant response options against enemy forces. This is accomplished through the layering of friendly forces and their operating risk level relative to one or more threat axes. This is also known as defence in depth. Forces may include airborne and ground alert aircraft as well as GBAD.	Posture affords defence in depth
		6.1.2 Match Raids	To counter enemy forces through the employment of a mix of friendly forces commensurate with the known threat. Force mix considerations include the relative number, type, and proficiency of forces, as well as the disposition and intent of the enemy.	Mix of friendly forces employed is commensurate with the known threat
		6.1.3 Warn Key Points	To assist in preparing key points against impending enemy attack through the timely provision of air raid warnings. This involves providing information regarding the nature and immediacy of the threat.	Threat warnings are provided in a timely manner
	6.2 Protect Airborne Assets	6.2.1 Protect Fighters	To prevent avoidable fighter aircraft losses due to enemy action through the provision of mutual support. This involves the provision of threat warnings and the co-ordination of friendly forces to support fighter aircraft that are defensive.	Mutual support prevents avoidable fighter losses
		6.2.2 Protect HVAs	To prevent the loss of mission critical elements by ensuring that they are positioned beyond the range at which enemy forces could present a direct threat. This involves the selection of stations or flight paths commensurate with the expected threat and retrograde decisions in reaction to an immediate threat.	Positioning decisions prevent the loss of HVAs

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19. ABSTRACT

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